3. Methane Emissions

Overview

U.S. Anthropogenic Methane Emissions, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	27.8	639.5
Change Compared to 2003 (Million Metric Tons)	0.2	5.6
Change from 2003 *(Percent)*	*0.9%*	*0.9%*
Change Compared to 1990 (Million Metric Tons)	-3.6	-81.9
Change from 1990 *(Percent)*	*-11.4%*	*-11.4%*

U.S. anthropogenic methane emissions in 2004 totaled 639.5 million metric tons carbon dioxide equivalent ($MMTCO_2e$),[63] or 27.8 million metric tons of methane, representing 9.0 percent of total U.S. greenhouse gas emissions. U.S. methane emissions in 2004 were 0.9 percent (5.6 $MMTCO_2e$) higher than their 2003 level of 633.9 $MMTCO_2e$ (Table 15), primarily as a result of an increase in emissions from landfills and smaller increases in emissions associated with animal waste, rice cultivation, and coal mining.

U.S. emissions of methane in 2004 were 11.4 percent (81.9 $MMTCO_2e$) below their 1990 level of 721.4 $MMTCO_2e$ (Figure 2). In addition to a reduction of 74.4 $MMTCO_2e$ (29 percent) in methane emissions from landfills since 1990, there was also a decrease of 29.5 $MMTCO_2e$ (30 percent) in methane emissions from coal mines over the same period (Table 16). The 30-percent decline in emissions from coal mining was the result of a 150-percent increase in methane recovery from coal mines and a shift in production away from gassy mines.

Methane emission estimates are much more uncertain than carbon dioxide emission estimates. Methane emissions usually are accidental or incidental to biological processes and may not be metered in any systematic way.[64] Thus, methane emission estimates must often rely on proxy measurements.

Estimated U.S. anthropogenic methane emissions for 2004 are based on incomplete data for several key sources; thus, the overall estimate is likely to be revised. Because emissions from three of these sources—coal mining, natural gas systems, and landfills—represented more than three-fifths of all U.S. methane emissions, comparisons between 2003 and 2004 numbers are more likely to be valid in terms of their direction than their magnitude. For example, because 2004 data on waste generation are not yet available, waste generation has been estimated from a simple regression equation with economic output as the independent variable. Less critical but still important data are also unavailable for

Principal Sources of U.S. Anthropogenic Methane Emissions, 1990-2004

	Million Metric Tons CO_2e		*Percent Change*	
Source	1990	2004	1990-2004	2003-2004
Energy	275.04	256.31	*-6.8%*	*
Waste Management	270.21	198.19	*-26.7%*	*2.4%*
Agriculture	173.42	182.25	*5.1%*	*0.5%*
Industrial Processes	2.70	2.70	*0.2%*	*4.1%*

*Less than 0.05 percent.

[63]Based on an estimated global warming potential factor of 23 for methane. For an expanded discussion of global warming potentials, see Chapter 1, page 10.

[64]Wherever possible, estimates of methane emissions are based on measured data. In some cases, however, measured data are incomplete or unavailable. In the absence of measured data, emissions are indexed to some known activity data, such as coal production or natural gas throughput, and multiplied by an emissions factor derived from a small sample of the relevant emissions source or through laboratory experiments. For a more detailed discussion of where measured data were used and how emissions factors were developed, see Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0638(2003) (Washington, DC, January 2005), web site www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf; and Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004* (to be published).

natural gas systems, such as miles of gas transmission and distribution pipeline.

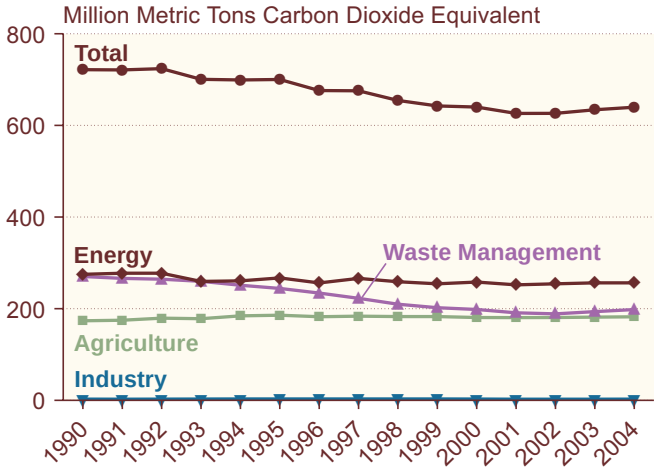
Energy Sources

U.S. methane emissions from energy sources in 2004 are estimated at 256.3 $MMTCO_2e$, equivalent to 40 percent of total methane emissions. The 2004 emission level is nearly unchanged from the 2003 level of 256.4 $MMTCO_2e$. Total methane emissions from energy sources in 2004 were 18.7 $MMTCO_2e$ below their 1990 level of 275.0 $MMTCO_2e$.

The drop in methane emissions from energy sources since 1990 can be traced primarily to an overall reduction in emissions from coal mines and secondarily to lower emissions from petroleum systems and stationary combustion. Methane emissions from coal mines dropped by 30 percent (29.5 $MMTCO_2e$) between 1990 and 2004. This decline resulted partly from the increased capture and use of methane from coal mine degasification systems and a shift in production away from some of the Nation's gassiest underground mines in Central Appalachia. Also, between 1990 and 2004, the share of coal production represented by underground mines declined from 41 percent to 34 percent. Methane emissions from underground mines tend to be higher than emissions from surface mines per ton of coal mined, because coal mined from the surface has been subjected to lower pressures and methane in the seams of surface mines has had earlier opportunities to migrate to the surface through cracks and fissures.

Methane emissions from petroleum systems dropped from 29.9 $MMTCO_2e$ in 1990 to 23.2 $MMTCO_2e$ in 2004.

Figure 2. U.S. Emissions of Methane by Source, 1990-2004



Source: Estimates presented in this chapter.

A decrease of 5.0 $MMTCO_2e$ in estimated methane emissions from stationary combustion (from 13.0 $MMTCO_2e$ in 1990 to 8.0 $MMTCO_2e$ in 2004) made a smaller contribution to the overall drop in emissions from energy sources between 1990 and 2004. Together, the declines in emissions from coal mining, petroleum systems, and stationary combustion more than compensated for the increase of 23.7 $MMTCO_2e$ in emissions from natural gas systems, attributed to increasing U.S. consumption of natural gas between 1990 and 2004.

Coal Mining

U.S. Methane Emissions from Coal Mining, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	3.0	68.2
Change Compared to 2003 (Million Metric Tons)	*	1.0
Change from 2003 *(Percent)*	*1.5%*	*1.5%*
Change Compared to 1990 (Million Metric Tons)	-1.3	-29.5
Change from 1990 *(Percent)*	*-30.2%*	*-30.2%*

*Less than 0.05 million metric tons.

The preliminary estimate of methane emissions from coal mines for 2004 is 68.2 $MMTCO_2e$ (Table 16), an increase of 1.5 percent (1.0 $MMTCO_2e$) from the 2003 level of 67.2 $MMTCO_2e$. This increase can be traced primarily to a 3.7-percent increase in coal production in 2004, centered predominantly in underground mines (up by 6.8 percent). U.S. coal production rose to 1.11 billion short tons in 2004, up from 1.07 billion short tons in 2003. The increase in coal production resulted from robust economic growth in 2004 that was accompanied by higher demand for coal to produce electricity and by record levels of coal exports.[65]

Methane emissions from coal mines have dropped by 30 percent, from 97.7 $MMTCO_2e$ in 1990 to 68.2 $MMTCO_2e$ in 2004. The decline is attributed to three important trends: (1) methane recovery from active coal mines for use as an energy resource increased from 6.1 $MMTCO_2e$ in 1990 to about 15.2. $MMTCO_2e$ in 2004; (2) methane emissions from degasification systems were reduced by nearly 8.5 $MMTCO_2e$, from 28.9 $MMTCO_2e$ in 1990 to

[65]Energy Information Administration, *U.S. Coal Supply and Demand: 2004 Review* (Washington, DC, April 2005), web site www.eia.doe.gov/cneaf/coal/page/special/feature04.pdf.

20.4 $MMTCO_2e$ in 2004; and (3) decreases in coal production from gassy mines, combined with enhanced methane recovery though degasification, caused methane emissions from ventilation systems at gassy mines to drop by about 12.8 $MMTCO_2e$, from 48.9 $MMTCO_2e$ in 1990 to 36.1 $MMTCO_2e$ in 2004 (Table 16).[66]

Abandoned coal mines represent a significant source of additional emissions that has not been incorporated into the overall estimate of methane emissions in this report because of uncertainties associated with the data. The text box on page 39 provides a discussion of those uncertainties and the potential magnitude of additional emissions.

Natural Gas Systems

U.S. Methane Emissions from Natural Gas Systems, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	6.6	152.6
Change Compared to 2003 (Million Metric Tons)	*	-0.5
Change from 2003 *(Percent)*	*-0.3%*	*-0.3%*
Change Compared to 1990 (Million Metric Tons)	1.0	23.7
Change from 1990 *(Percent)*	*18.4%*	*18.4%*

*Less than 0.05 million metric tons.

At 152.6 $MMTCO_2e$, 2004 estimated methane emissions from natural gas systems were down by 0.3 percent from the 153.1 $MMTCO_2e$ emitted in 2003 (Table 17). The 2004 estimate is preliminary, however, because pipeline data for 2004 have not been finalized as of the publication of this report. The estimated 2004 emissions level is 18 percent (23.7 $MMTCO_2e$) above the 1990 level (128.9 $MMTCO_2e$), with more than three-fifths of the increase attributable to increased mileage of transmission and distribution pipelines and almost two-fifths attributable to increases in natural gas production.[67]

Petroleum Systems

U.S. Methane Emissions from Petroleum Systems, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	1.0	23.2
Change Compared to 2003 (Million Metric Tons)	*	-0.1
Change from 2003 *(Percent)*	*-0.4%*	*-0.4%*
Change Compared to 1990 (Million Metric Tons)	-0.3	-6.7
Change from 1990 *(Percent)*	*-22.5%*	*-22.5%*

*Less than 0.05 million metric tons.

Methane emissions from petroleum systems in 2004 are estimated at 23.2 $MMTCO_2e$, nearly unchanged from their 2003 level and down by 22 percent (6.7 $MMTCO_2e$) from their 1990 level of 29.9 $MMTCO_2e$. The decline in emissions from this source is almost exclusively due to a 26-percent reduction in domestic oil production from 1990 to 2004. Approximately 92 percent (21.4 $MMTCO_2e$) of all U.S. emissions from petroleum systems occur during oil exploration and production (Table 18). A much smaller portion of methane emissions from petroleum systems can be traced to refineries (0.6 $MMTCO_2e$) and transportation of crude oil (1.1 $MMTCO_2e$).

Stationary Combustion

U.S. methane emissions from stationary combustion in 2004 were 8.0 $MMTCO_2e$, down by 6.3 percent from their 2003 level of 8.5 $MMTCO_2e$ and 39 percent below their 1990 level of 13.0 $MMTCO_2e$ (Table 19). Residential wood consumption typically accounts for about 85 percent of methane emissions from stationary combustion. Methane emissions are the result of incomplete combustion, and residential woodstoves and fireplaces provide much less efficient combustion than industrial or utility boilers. Estimates of emissions from residential wood

[66]The U.S. Environmental Protection Agency (EPA) currently accounts for methane recovery from coal mines in the year the coal seam is mined through. The relationship betweeen estimates of emissions from degasification and estimates of gas recovery is under review and may be revised in the future.

[67]The EPA estimates that companies participating in the Natural Gas STAR program together avoided emissions of 27.0 $MMTCO_2e$ of methane from the natural gas system in 2004 (Table 17). Program participants report annually on emissions reductions achieved through such activities as equipment replacement, enhanced inspection and maintenance, and improved operations management. Participating companies may either use their own techniques to estimate reductions achieved or employ default values developed by the EPA and the Gas Technology Institute (formerly the Gas Research Institute).

U.S. Methane Emissions from Stationary Combustion, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	0.3	8.0
Change Compared to 2003 (Million Metric Tons)	*	-0.5
Change from 2003 *(Percent)*	*-6.3%*	*-6.3%*
Change Compared to 1990 (Million Metric Tons)	-0.2	-5.0
Change from 1990 *(Percent)*	*-38.7%*	*-38.7%*

*Less than 0.05 million metric tons.

combustion have fallen by 43 percent, from 11.8 $MMTCO_2e$ in 1990 to 6.7 $MMTCO_2e$ in 2004, although these estimates are very uncertain.[68]

The universe of wood consumers is large and heterogeneous, and the Energy Information Administration (EIA) collects data on residential wood consumption only at 4-year intervals in its Residential Energy Consumption Survey (RECS). The most recently published EIA data on residential wood consumption are from the 2001 RECS.[69] Updated data on residential wood consumption for calendar year 2004 will be available from the 2005 RECS.

Mobile Combustion

Estimated U.S. methane emissions from mobile combustion in 2004 were 4.4 $MMTCO_2e$, up by 0.7 percent from the 2003 level but 22 percent lower than the 1990 level of 5.6 $MMTCO_2e$ (Table 20). Methane emissions from passenger cars have declined since 1990 as older vehicles with catalytic converters that are less efficient at destroying methane have been taken off the road. Estimates of methane emissions from mobile sources have been revised downward in the last two annual editions of this report, reflecting a change in the source of data for vehicle miles traveled and a related adjustment in the emission factors for light-duty trucks.[70]

Waste Management

Methane emissions from waste management, at 198.2 $MMTCO_2e$, accounted for 31 percent of U.S. anthropogenic methane emissions in 2004 (Figure 2). Emissions from this source have fallen by 27 percent (72.0 $MMTCO_2e$) from their 1990 level of 270.2 $MMTCO_2e$. Landfills represent 92 percent (182.6 $MMTCO_2e$) of the methane emissions from waste management in 2004, and they are the largest single source of U.S. anthropogenic methane emissions (Table 15). The remainder of emissions from waste management (15.6 $MMTCO_2e$) is associated with domestic wastewater treatment. Estimated emissions from waste management would increase if sufficient information were available to develop a reliable estimate of emissions from industrial wastewater treatment.

EIA's estimates of methane emissions from landfills include emissions from both municipal solid waste landfills and industrial landfills. Estimated methane emissions from industrial landfills are based on a

U.S. Methane Emissions from Mobile Sources, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	0.2	4.4
Change Compared to 2003 (Million Metric Tons)	*	*
Change from 2003 *(Percent)*	*0.7%*	*0.7%*
Change Compared to 1990 (Million Metric Tons)	-0.1	-1.2
Change from 1990 *(Percent)*	*-22.1%*	*-22.1%*

*Less than 0.05 million metric tons.

[68]For further details see Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0638(2003) (Washington, DC, January 2005), web site www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf; and Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004* (to be published).

[69]U.S. Energy Information Administration, Residential Energy Consumption Survey, web site www.eia.doe.gov/emeu/recs/recs2001/publicuse2001.html.

[70]For a more detailed discussion of the revisions in estimation methods for mobile sources, see Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0638(2003) (Washington, DC, January 2005), web site www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf; and Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004* (to be published).

Methane Emissions from Abandoned Coal Mines

Thousands of coal mines in the United States have been closed and abandoned during the past 100 years. The U.S. Department of Labor's Mine Safety and Health Administration (MSHA) estimates that since 1980 more than 7,500 coal mines have been abandoned, and many continue to emit methane. In an April 2004 report,[a] the U.S. Environmental Protection Agency (EPA) estimated that methane emissions from abandoned coal mines ranged between 3.0 $MMTCO_2e$ and 4.6 $MMTCO_2e$ in 1990, and between 4.6 $MMTCO_2e$ and 6.4 $MMTCO_2e$ in 2002. More recently, the EPA estimated methane emissions of 7.0 $MMTCO_2e$ from abandoned underground coal mines in 2003, up from 6.7 $MMTCO_2e$ in 1990 but down from a peak of 8.4 $MMTCO_2e$ in 2000 due to a decline in the number of gassy mines being abandoned.[b] Because access to abandoned mines is limited and a systematic measurement program at those sites would be time-intensive and costly, the EPA estimates rely on actual emissions data from when the mines were operating and assume a decline function in emissions based on mine and coal-seam characteristics.

The most important variable in determining the amount of methane emissions from an abandoned mine is its post-mining status—whether the mine has been sealed, flooded, or continues to be vented. Sealed and flooded mines have much lower rates of emissions than vented mines. Another variable deemed important is whether the mine was gassy (emitting more than 100,000 cubic feet per day) when it was operating. Gassy mines are estimated to emit 98 percent of all methane emissions from operating coal mines, and the EPA assumes that abandoned mines which had been gassy when operating represent a similarly predominant portion of emissions from abandoned mines. The EPA's 2004 study thus focuses on abandoned mines that had been gassy prior to closure. Of the 364 gassy mines abandoned since 1972, the EPA has data on the status of a portion of them (i.e., whether the mines were sealed, flooded, or continue to be vented), calculates percentage shares of emissions by their respective status, and then assumes that those shares apply to mines for which it does not have data.

For abandoned mines that have been vented, the EPA derives an emissions decline curve based on three primary factors: adsorption isotherms by coal basin, coal permeability estimates, and estimates of pressure at abandonment. For mines that are flooded, the EPA assumes a decline curve equation based on measurements taken from eight abandoned mines in two basins. The EPA treats sealed mines similarly to those vented, adjusting the initial emissions rate and length of time for emissions to dissipate, given the slower release rate from sealed vents.

The EPA sought to calibrate its estimation methodology to field measurements, but restricted access precluded measurement at all but seven mines. Although results from those mines suggested the general accuracy of the estimation method, EIA believes the methodology has not yet been validated. EIA will reconsider including estimates of methane emissions from abandoned mines in its overall estimates of U.S. greenhouse gas emissions should additional field data confirm the EPA methodology.

[a]U.S. Environmental Protection Agency, Coalbed Methane Outreach Program, *Methane Emissions from Abandoned Coal Mines in the United States: Emission Inventory Methodology and 1990-2002 Emissions Estimates* (Washington, DC, April 2004), web site www.epa.gov/cmop/pdf/amm_final_report.pdf.

[b]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

methodology developed by the EPA and represent 7 percent of emissions from municipal solid waste landfills.[71]

EIA has revised its estimates of methane recovered for energy from landfills. Previous editions of this report erroneously included the avoided emissions of carbon dioxide from fossil fuel combustion displaced by landfill gas-to-energy operations in the estimate of methane recovered. This resulted in double counting of the impacts of fossil fuel displacement by landfill gas-to-energy. For this year's report, the avoided emissions have been removed from estimates going back to 1990. Similarly, estimates of methane recovered and flared have been lowered to eliminate some potential double counting associated with methane recovery for energy projects, as flares are typically used for backup systems at plants that recover methane for energy. Together, these revisions have raised the EIA estimates of overall methane emissions from waste management

[71]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

by increments ranging from 8 $MMTCO_2e$ for 1990 to 21 $MMTCO_2e$ for 2003.

Landfills

U.S. Methane Emissions from Landfills, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	7.9	182.6
Change Compared to 2003 (Million Metric Tons)	0.2	4.5
Change from 2003 *(Percent)*	*2.5%*	*2.5%*
Change Compared to 1990 (Million Metric Tons)	-3.2	-74.4
Change from 1990 *(Percent)*	*-29.0%*	*-29.0%*

Due to increased levels of waste disposed in landfills, estimated methane emissions from landfills rose to 182.6 $MMTCO_2e$ in 2004, 2.5 percent (4.5 $MMTCO_2e$) above the 2003 level of 178.1 $MMTCO_2e$ but still 29 percent (74.4 $MMTCO_2e$) below the 1990 level of 257.0 $MMTCO_2e$ (Table 21). The dramatic decrease in methane emissions since 1990 is directly attributable to a 100.4 $MMTCO_2e$ increase in methane captured at landfills that otherwise would have been emitted to the atmosphere. Of the 122.1 $MMTCO_2e$ of methane believed to be captured from this source in 2004, 63.3 $MMTCO_2e$ was recovered for energy use, and 58.9 $MMTCO_2e$ was recovered and flared. In 2004, methane recovery for energy increasingly took the form of direct use of medium-Btu gas in industrial boilers. The acceleration of this practice was driven by higher natural gas prices, which made landfill gas more competitive.[72]

Estimates of methane recovered for energy are drawn from data collected by the U.S. Environmental Protection Agency's (EPA's) Landfill Methane Outreach Program.[73] Estimates of methane recovered and flared are based on data collected from flaring equipment vendors, in conjunction with data reported on Form EIA-1605.[74] There is less uncertainty in the estimate of methane recovered and used for energy, and it is likely that estimates of methane flared are biased downward due to a lack of comprehensive industry data.

The rapid growth in methane recovery has been aided by a combination of regulatory and tax policy. The Federal Section 29 (of the Internal Revenue Code) tax credit for alternative energy sources, added to the tax code as part of the Crude Oil Windfall Profits Act of 1980, provided a subsidy roughly equivalent to 1 cent per kilowatthour for electricity generated from landfill gas; however, the tax credit expired on June 30, 1998. As part of the American Jobs Creation Act of 2004, a tax credit for electricity generation using landfill gas was added to Section 45 of the Internal Revenue Code. The credit was augmented under the Energy Policy Act of 2005, which extended the credit period—previously 5 years from the original date of service—to 10 years from the original date of service. To be eligible for the credit, a landfill gas-to-energy project must be placed in service between October 22, 2004, and December 31, 2007. Those facilities that qualify are eligible for a 5-year tax credit valued at 0.9 cent per kilowatthour.

Increases in methane recovery have also resulted from the implementation of the EPA's New Source Performance Standards and Emission Guidelines. The regulations require all landfills with more than 2.5 million metric tons of waste in place and annual emissions of nonmethane organic compounds (NMOCs) exceeding 50 metric tons to collect and burn their landfill gas, either by flaring or for use as an energy source.

Domestic and Commercial Wastewater Treatment

With the U.S. population growing slowly, methane emissions from domestic and commercial wastewater treatment are estimated to have grown by nearly 1.0 percent between 2003 and 2004 to 15.6 $MMTCO_2e$—about 18 percent above the 1990 level of 13.2 $MMTCO_2e$ (Table 15). Methane emissions from industrial wastewater treatment are discussed in the text box on page 41.

Methane emissions from domestic and commercial wastewater treatment are a function of the share of organic matter in the wastewater stream and the conditions under which it decomposes. Wastewater may be treated aerobically or anaerobically. Because aerobic decomposition does not yield methane, whereas anaerobic decomposition does, the method of treatment is a critical determinant of emissions; however, there is little

[72]Personal communication with Brian Guzzone, U.S. Environmental Protection Agency, Landfill Methane Outreach Program.
[73]U.S. Environmental Protection Agency, Landfill Methane Outreach Program, web site www.epa.gov/lmop.
[74]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html; and U.S. Energy Information Administration, Voluntary Reporting of Greenhouse Gases database, web site www.eia.doe.gov/oiaf/1605/databases.html.

information available on wastewater treatment methods. Data on flaring or energy recovery from methane generated by wastewater are also sparse. EIA believes that emissions from this source are relatively small, representing less than 3 percent of all U.S. methane emissions in 2004. Thus, emissions are estimated using a default per-capita emissions factor and U.S. population data.

U.S. Methane Emissions from Domestic and Commercial Wastewater Treatment, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	0.7	15.6
Change Compared to 2003 (Million Metric Tons)	*	0.2
Change from 2003 *(Percent)*	*1.0%*	*1.0%*
Change Compared to 1990 (Million Metric Tons)	0.1	2.4
Change from 1990 *(Percent)*	*18.0%*	*18.0%*

*Less than 0.05 million metric tons.

Agricultural Sources

Estimated methane emissions from agricultural sources, at 182.3 $MMTCO_2e$ in 2004, represent 28.5 percent of total U.S. anthropogenic methane emissions (Table 15). Agricultural methane emissions increased by less than 1 percent (0.9 $MMTCO_2e$) from 2003 to 2004, as a small decrease in emissions from enteric fermentation was offset by increases in emissions from animal waste management, rice cultivation, and crop residue burning. Of total estimated methane emissions from agricultural activities, 93 percent (170.0 $MMTCO_2e$) results from livestock management, of which 67.8 percent (115.2 $MMTCO_2e$) can be traced to enteric fermentation in ruminant animals and the remainder (54.7 $MMTCO_2e$)

Methane Emissions from Industrial Wastewater Treatment

When wastewater containing large amounts of organic material is treated through anaerobic decomposition, methane is emitted. The best estimate of those emissions would be based on a systematic measurement of all point sources; however, the number and diversity of U.S. industrial wastewater sources make such an approach unaffordable and impractical. As an alternative, methane emissions from industrial wastewater treatment are calculated by the following equation:

$$M = P \times O \times COD \times A \times EF \quad ,$$

where M = methane emissions, P = product output, O = wastewater outflow per unit of product output, COD = organic loading in outflow, A = percentage of outflow treated anaerobically, and EF = emissions factor for anaerobically treated outflow.

The Intergovernmental Panel on Climate Change (IPCC), in its *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*,[a] provides default data for wastewater generation and *COD* on an industry-specific basis. The default data, often based on one or two literature sources, are assumed to have an uncertainty range of minus 50 percent to plus 100 percent (although no justification for the range is provided). The IPCC also provides a single default factor of 0.25 kilograms methane per kilogram of *COD*, premised on a general approximation of the theoretical maximum for this emission factor, and identifies an uncertainty of plus or minus 30 percent for this estimate.

There are currently no specific U.S. data that could be used to improve on the IPCC defaults, and the uncertainties make it impossible for the Energy Information Administration to provide a reliable estimate of emissions from this source. It can be noted, however, that depending on the extent to which industrial wastewater from such industries as meat and poultry processing, pulp and paper manufacturing, and vegetable, fruit, and juice processing—which is likely to have a high content of organic material—is treated anaerobically, excluding the methane emissions that would result from the U.S. emissions total will tend to produce an underestimate of U.S. methane emissions. The U.S. Environmental Protection Agency estimates that U.S. methane emissions from industrial wastewater treatment could be as high as 16.9 $MMTCO_2e$ in 2003.[b] If more comprehensive data on industrial wastewater flows become available, EIA will consider adding this source to its estimate of U.S. methane emissions.

[a]Intergovernmental Panel On Climate Change, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Montreal, Canada, May 2000), web site www.ipcc-nggip.iges.or.jp/public/gp/english/.

[b]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

to anaerobic decomposition of livestock wastes. A small portion of U.S. agricultural methane emissions result from crop residue burning and wetland rice cultivation.

Enteric Fermentation in Domesticated Animals

U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	5.0	115.2
Change Compared to 2003 (Million Metric Tons)	*	-0.9
Change from 2003 *(Percent)*	*-0.8%*	*-0.8%*
Change Compared to 1990 (Million Metric Tons)	-0.2	-4.4
Change from 1990 *(Percent)*	*-3.7%*	*-3.7%*

*Less than 0.05 million metric tons.

In 2004, estimated methane emissions from enteric fermentation in domesticated animals declined by 0.8 percent to 115.2 $MMTCO_2e$ (Table 22). Because 95 percent of all emissions from enteric fermentation is attributable to cattle (109.9 $MMTCO_2e$), trends in emissions correlate with trends in cattle populations. Between 2003 and 2004, cattle populations were nearly constant, with small declines in all population categories offset somewhat by increases in populations of beef cattle on feedlots. Estimated methane emissions from enteric fermentation in 2004 are 3.7 percent below their 1990 level of 119.6 $MMTCO_2e$.

Solid Waste of Domesticated Animals

Estimated methane emissions from the solid waste of domesticated animals increased from 54.2 $MMTCO_2e$ in 2003 to 54.7 $MMTCO_2e$ in 2004 (Table 23). The increase reinforced a larger trend over the past decade: in 2004, emissions from the solid waste of domesticated animals were 11.2 $MMTCO_2e$ above their 1990 level of 43.5 $MMTCO_2e$, an increase of 26 percent. Between 1990 and 2004, there was a shift in livestock management to larger facilities, which are believed to be more likely to manage waste using liquid systems that tend to promote methane generation.[75]

Rice Cultivation

Estimated methane emissions from U.S. rice cultivation increased to 11.0 $MMTCO_2e$ in 2004 from 9.8 $MMTCO_2e$ in 2003 (Table 15). The rise was the result of a 12-percent jump in the number of acres harvested.[76] All U.S. rice-producing States saw increases in acres harvested during 2004, and total methane emissions from rice cultivation in 2004 were 18 percent (1.7 $MMTCO_2e$) higher than in 1990.

Burning of Crop Residues

Crop residue burning, the smallest contributor to U.S. methane emissions, represents less than 1 percent of total U.S. methane emissions. Estimated 2004 methane emissions from the burning of crop residues were 1.3 $MMTCO_2e$, up by 12 percent from 2003 and 27 percent above their 1990 level of 1.0 $MMTCO_2e$ (Table 15). The increase from 2003 to 2004 is attributable mainly to large increases in corn and soybean production.

U.S. Methane Emissions from Solid Waste of Domesticated Animals, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	2.4	54.7
Change Compared to 2003 (Million Metric Tons)	*	0.5
Change from 2003 *(Percent)*	*0.9%*	*0.9%*
Change Compared to 1990 (Million Metric Tons)	0.5	11.2
Change from 1990 *(Percent)*	*25.8%*	*25.8%*

*Less than 0.05 million metric tons.

[75]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-04-003 (Washington, DC, April 2005), p. 200, web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

[76]U.S. Department of Agriculture, National Agricultural Statistics Service, *Crop Production—Annual Summary* (Washington, DC, various years), web site http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bban.

Industrial Processes

U.S. Methane Emissions from Industrial Processes, 1990-2004

	Methane	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	0.1	2.7
Change Compared to 2003 (Million Metric Tons)	*	0.1
Change from 2003 *(Percent)*	*4.1%*	*4.1%*
Change Compared to 1990 (Million Metric Tons)	*	*
Change from 1990 *(Percent)*	*0.2%*	*0.2%*

*Less than 0.05 million metric tons.

Chemical Production

The preliminary estimate of methane emissions from U.S. chemical production in 2004 is 1.6 $MMTCO_2e$, up by 6 percent from the 2003 level of 1.5 $MMTCO_2e$. Methane emissions from chemical production in 2004 were 25 percent above their 1990 level of 1.3 $MMTCO_2e$. The increase is attributable to increased production of carbon black, ethylene, and styrene, which more than offset a drop in methanol production (Table 24).[77]

Iron and Steel Production

With production of pig iron rebounding from a 2-decade low in 2003,[78] methane emissions from iron and steel production rose to an estimated 1.1 $MMTCO_2e$ in 2004, a 2.2-percent increase from 2003 but still 23 percent below their 1990 level of 1.4 $MMTCO_2e$ (Table 24).

[77] American Chemistry Council (formerly the Chemical Manufacturers Association), *Guide to the Business of Chemistry*, Table 3.12, "Production of the Top 100 Chemicals" (Washington, DC, 2003).
[78] American Iron and Steel Institute, *Annual Statistical Report*, Tables 26, 31, and 32 (Washington, DC, various years).

Table 15. U.S. Methane Emissions from Anthropogenic Sources, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Energy Sources										
Coal Mining	97.7	73.4	80.4	75.6	71.7	68.5	68.0	64.7	67.2	68.2
Natural Gas Systems	128.9	138.1	144.3	143.9	144.2	151.0	147.0	154.0	153.1	152.6
Petroleum Systems	29.9	26.4	26.3	25.5	24.0	23.8	23.7	23.5	23.3	23.2
Stationary Combustion	13.0	13.3	10.1	9.1	9.6	10.1	8.7	7.6	8.5	8.0
Mobile Sources	5.6	5.1	5.1	4.8	4.8	4.7	4.6	4.6	4.3	4.4
Total Energy Sources	**275.0**	**256.3**	**266.2**	**258.9**	**254.4**	**258.1**	**252.0**	**254.3**	**256.4**	**256.3**
Waste Management										
Landfills	257.0	219.8	208.1	195.0	187.4	183.3	175.8	173.4	178.1	182.6
Wastewater Treatment	13.2	14.3	14.5	14.7	14.8	15.0	15.2	15.3	15.5	15.6
Total Waste Management	**270.2**	**234.2**	**222.6**	**209.7**	**202.2**	**198.3**	**191.0**	**188.7**	**193.6**	**198.2**
Agricultural Sources										
Enteric Fermentation	119.6	122.0	119.1	117.2	117.3	116.3	115.1	115.7	116.2	115.2
Animal Waste	43.5	49.7	52.7	53.6	52.7	52.8	53.3	53.7	54.2	54.7
Rice Cultivation	9.3	9.4	10.3	10.7	11.5	10.2	10.7	10.2	9.8	11.0
Crop Residue Burning	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.2	1.3
Total Agricultural Sources	**173.4**	**182.2**	**183.3**	**182.6**	**182.5**	**180.5**	**180.3**	**180.6**	**181.3**	**182.3**
Industrial Processes	**2.7**	**3.1**	**3.1**	**3.1**	**3.1**	**2.9**	**2.5**	**2.6**	**2.6**	**2.7**
Total	**721.4**	**675.8**	**675.2**	**654.2**	**642.2**	**639.8**	**625.8**	**626.2**	**633.9**	**639.5**
Million Metric Tons Methane										
Energy Sources										
Coal Mining	4.25	3.19	3.50	3.29	3.12	2.98	2.96	2.81	2.92	2.96
Natural Gas Systems	5.60	6.00	6.27	6.26	6.27	6.57	6.39	6.70	6.66	6.64
Petroleum Systems	1.30	1.15	1.14	1.11	1.04	1.03	1.03	1.02	1.01	1.01
Stationary Combustion	0.56	0.58	0.44	0.39	0.42	0.44	0.38	0.33	0.37	0.35
Mobile Sources	0.24	0.22	0.22	0.21	0.21	0.21	0.20	0.20	0.19	0.19
Total Energy Sources	**11.96**	**11.14**	**11.57**	**11.25**	**11.06**	**11.22**	**10.96**	**11.06**	**11.15**	**11.14**
Waste Management										
Landfills	11.17	9.56	9.05	8.48	8.15	7.97	7.64	7.54	7.74	7.94
Wastewater Treatment	0.58	0.62	0.63	0.64	0.65	0.65	0.66	0.67	0.67	0.68
Total Waste Management	**11.75**	**10.18**	**9.68**	**9.12**	**8.79**	**8.62**	**8.30**	**8.20**	**8.42**	**8.62**
Agricultural Sources										
Enteric Fermentation	5.20	5.30	5.18	5.10	5.10	5.06	5.01	5.03	5.05	5.01
Animal Waste	1.89	2.16	2.29	2.33	2.29	2.29	2.32	2.33	2.36	2.38
Rice Cultivation	0.40	0.41	0.45	0.47	0.50	0.44	0.47	0.45	0.43	0.48
Crop Residue Burning	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Total Agricultural Sources	**7.54**	**7.92**	**7.97**	**7.94**	**7.94**	**7.85**	**7.84**	**7.85**	**7.88**	**7.92**
Industrial Processes	**0.12**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.11**	**0.11**	**0.11**	**0.12**
Total	**31.36**	**29.38**	**29.36**	**28.44**	**27.92**	**27.82**	**27.21**	**27.23**	**27.56**	**27.80**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: EIA estimates presented in this chapter. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.83-4.84, web site www.ipcc.ch/pub/guide.htm; and U.S. U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

Table 16. U.S. Methane Emissions from Coal Mining and Post-Mining Activities, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Surface Mining										
Mining	9.8	10.6	10.9	11.4	11.5	11.4	12.1	12.0	11.7	11.9
Post-Mining	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.0
Subtotal	*10.7*	*11.5*	*11.8*	*12.4*	*12.5*	*12.4*	*13.2*	*13.0*	*12.7*	*13.0*
Underground Mining										
Ventilation (Gassy Mines)[a]	48.9	39.3	41.2	41.5	40.6	38.3	37.2	34.7	33.4	36.1
Ventilation (Nongassy Mines)	0.6	0.8	0.8	0.9	0.9	0.9	0.8	0.8	0.8	0.8
Degasification Systems	28.9	23.5	24.4	21.8	18.1	20.0	21.3	22.9	24.6	20.4
Post-Mining	14.7	14.2	14.6	14.5	13.6	12.9	13.2	12.4	12.2	13.0
Methane Recovery for Energy (-)	6.1	16.0	12.5	15.5	13.9	16.0	17.7	19.1	16.5	15.2
Subtotal	*87.0*	*61.9*	*68.6*	*63.2*	*59.2*	*56.1*	*54.8*	*51.7*	*54.5*	*55.2*
Net Emissions	**97.7**	**73.4**	**80.4**	**75.6**	**71.7**	**68.5**	**68.0**	**64.7**	**67.2**	**68.2**
Million Metric Tons Methane										
Surface Mining										
Mining	0.43	0.46	0.47	0.49	0.50	0.49	0.53	0.52	0.51	0.52
Post-Mining	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.05
Subtotal	*0.46*	*0.50*	*0.51*	*0.54*	*0.54*	*0.54*	*0.57*	*0.57*	*0.55*	*0.56*
Underground Mining										
Ventilation (Gassy Mines)[a]	2.13	1.71	1.79	1.80	1.76	1.67	1.62	1.51	1.45	1.57
Ventilation (Nongassy Mines)	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04
Degasification Systems	1.26	1.02	1.06	0.95	0.79	0.87	0.93	1.00	1.07	0.89
Post-Mining	0.64	0.62	0.63	0.63	0.59	0.56	0.57	0.54	0.53	0.57
Methane Recovery for Energy (-)	0.26	0.69	0.54	0.67	0.60	0.70	0.77	0.83	0.72	0.66
Subtotal	*3.78*	*2.69*	*2.98*	*2.75*	*2.57*	*2.44*	*2.38*	*2.25*	*2.37*	*2.40*
Net Emissions	**4.25**	**3.19**	**3.50**	**3.29**	**3.12**	**2.98**	**2.96**	**2.81**	**2.92**	**2.96**

[a]A "gassy" mine is an underground mine with ventilation emissions of 100,000 cubic feet of methane or more per day, as measured by the U.S. Mine Safety and Health Administration.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: Coal production numbers from Energy Information Administration, *Coal Production*, DOE/EIA-0118 (Washington, DC, various years), and *Coal Industry Annual*, DOE/EIA-0584 (Washington, DC, various years). Methane recovery rates from U.S. Environmental Protection Agency, Office of Air and Radiation, Non-CO_2 Gases and Sequestration Branch, Coalbed Methane Outreach Program. Ventilation data for 1985, 1988, and 1990 provided by G. Finfinger, U.S. Department of the Interior, Bureau of Mines, Pittsburgh Research Center. Ventilation data for all other years provided by U.S. Environmental Protection Agency, Office of Air and Radiation, Non-CO_2 Gases and Sequestration Branch, Coalbed Methane Outreach Program.

Table 17. U.S. Methane Emissions from Natural Gas Systems, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Production	33.8	36.3	38.0	38.4	37.3	39.9	42.0	42.4	42.9	42.8
Natural Gas Processing	14.9	16.9	16.4	16.0	16.1	16.4	16.0	15.5	14.4	14.4
Transmission and Storage	48.3	48.5	52.1	51.0	52.8	55.4	49.0	55.6	54.7	54.3
Distribution	32.0	36.3	37.8	38.5	38.0	39.3	40.0	40.5	41.2	41.2
Total	**128.9**	**138.1**	**144.3**	**143.9**	**144.2**	**151.0**	**147.0**	**154.0**	**153.1**	**152.6**
Natural Gas STAR Reductions	0.3	8.3	10.7	12.9	14.5	16.5	19.2	25.9	25.9	27.0
Million Metric Tons Methane										
Production	1.47	1.58	1.65	1.67	1.62	1.73	1.83	1.84	1.86	1.86
Natural Gas Processing	0.65	0.73	0.71	0.69	0.70	0.71	0.69	0.67	0.63	0.63
Transmission and Storage	2.10	2.11	2.27	2.22	2.30	2.41	2.13	2.42	2.38	2.36
Distribution	1.39	1.58	1.64	1.67	1.65	1.71	1.74	1.76	1.79	1.79
Total	**5.60**	**6.00**	**6.27**	**6.26**	**6.27**	**6.57**	**6.39**	**6.70**	**6.66**	**6.64**
Natural Gas STAR Reductions	0.01	0.36	0.47	0.56	0.63	0.72	0.84	1.13	1.13	1.17

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding. Data for Natural Gas STAR reductions are estimates provided by the EPA, based on annual submissions to the EPA by companies participating in the program, which report activities undertaken to avoid methane emissions from natural gas and petroleum systems.

Sources: National Risk Management Research Laboratory, *Methane Emissions From the Natural Gas Industry*, Vol. 2, Technical Report, GRI-94/0257.1 and EPA-600-R-96-08 (Research Triangle Park, NC, June 1996), Appendix A; American Gas Association, *Gas Facts* (various years); Energy Information Administration, *Natural Gas Annual,* DOE/EIA-0131 (various years); Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2004/07) (Washington, DC, July 2004); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years).

Table 18. U.S. Methane Emissions from Petroleum Systems, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Refineries	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Exploration and Production	29.0	25.5	25.5	24.7	23.2	22.9	22.9	22.6	22.4	21.4
Crude Oil Transportation	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	1.1
Total	**29.9**	**26.4**	**26.3**	**25.5**	**24.0**	**23.8**	**23.7**	**23.5**	**23.3**	**23.2**
Million Metric Tons Methane										
Refineries	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Exploration and Production	1.26	1.11	1.11	1.07	1.01	1.00	0.99	0.98	0.97	0.93
Crude Oil Transportation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
Total	**1.30**	**1.15**	**1.14**	**1.11**	**1.04**	**1.03**	**1.03**	**1.02**	**1.01**	**1.01**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, *Draft Estimates of Methane Emissions from the U.S. Oil Industry* (Draft Report, Washington, DC); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years); and *Oil and Gas Journal*, Worldwide Refining Issue and Pipeline Economics Issue (various years).

Table 19. U.S. Methane Emissions from Stationary Combustion Sources, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
	Thousand Metric Tons Carbon Dioxide Equivalent									
Residential										
Coal	*	*	*	*	0	0	0	0	0	0
Fuel Oil[a]	113	107	101	89	96	105	105	99	105	109
Natural Gas	100	119	113	103	107	113	108	111	116	111
LPG	10	13	12	12	14	15	14	14	14	14
Wood	11,783	12,067	8,782	7,849	8,396	8,782	7,504	6,348	7,281	6,733
Total	**12,006**	**12,306**	**9,008**	**8,053**	**8,613**	**9,014**	**7,731**	**6,573**	**7,515**	**6,968**
Commercial										
Coal	29	28	30	23	24	20	21	21	19	20
Fuel Oil[a]	16	12	10	9	9	10	10	9	11	12
Natural Gas	71	86	88	82	83	86	83	86	88	82
LPG	2	2	2	2	3	3	3	3	2	3
Wood	3	3	3	3	4	4	3	3	3	3
Total	**120**	**131**	**133**	**120**	**121**	**122**	**119**	**121**	**123**	**119**
Industrial										
Coal	151	133	130	123	121	122	122	112	113	112
Fuel Oil[a]	32	27	24	20	18	20	21	17	19	23
Natural Gas	263	307	308	303	291	295	270	274	264	271
LPG	51	66	68	65	71	72	65	70	67	69
Wood	89	104	107	99	100	101	89	86	84	89
Total	**585**	**637**	**637**	**610**	**601**	**609**	**566**	**559**	**547**	**564**
Electric Power										
Coal	225	256	262	267	268	281	273	275	280	281
Fuel Oil[a]	19	10	12	17	16	14	16	11	14	14
Natural Gas	7	9	9	10	11	12	12	13	12	12
Wood	1	0	0	0	0	0	0	0	0	0
Total	**252**	**275**	**283**	**294**	**294**	**307**	**302**	**298**	**306**	**308**
Total All Sectors										
Coal	405	416	423	413	412	423	416	408	413	414
Fuel Oil[a]	180	156	147	135	139	149	153	137	149	158
Natural Gas	441	521	518	499	492	505	473	484	479	476
LPG	62	81	82	78	88	90	82	87	83	86
Wood	11,875	12,174	8,891	7,951	8,499	8,886	7,595	6,436	7,367	6,825
Total	**12,964**	**13,349**	**10,061**	**9,076**	**9,630**	**10,052**	**8,718**	**7,551**	**8,491**	**7,959**

*Less than 500 metric tons carbon dioxide equivalent.
[a]Fuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.
P = preliminary data.
See notes and sources at end of table.

Table 19. U.S. Methane Emissions from Stationary Combustion Sources, 1990 and 1996-2004 (Continued)

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
	Thousand Metric Tons Methane									
Residential										
Coal	*	*	*	*	0	0	0	0	0	0
Fuel Oil[a]	5	5	4	4	4	5	5	4	5	5
Natural Gas	4	5	5	4	5	5	5	5	5	5
LPG	*	1	1	1	1	1	1	1	1	1
Wood	512	525	382	341	365	382	326	276	317	293
Total	**522**	**535**	**392**	**350**	**374**	**392**	**336**	**286**	**327**	**303**
Commercial										
Coal	1	1	1	1	1	1	1	1	1	1
Fuel Oil[a]	1	1	*	*	*	*	*	*	*	1
Natural Gas	3	4	4	4	4	4	4	4	4	4
LPG	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*
Total	**5**	**6**	**6**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Industrial										
Coal	7	6	6	5	5	5	5	5	5	5
Fuel Oil[a]	1	1	1	1	1	1	1	1	1	1
Natural Gas	11	13	13	13	13	13	12	12	11	12
LPG	2	3	3	3	3	3	3	3	3	3
Wood	4	5	5	4	4	4	4	4	4	4
Total	**25**	**28**	**28**	**27**	**26**	**26**	**25**	**24**	**24**	**25**
Electric Power										
Coal	10	11	11	12	12	12	12	12	12	12
Fuel Oil[a]	1	*	1	1	1	1	1	*	1	1
Natural Gas	*	*	*	*	*	1	1	1	1	1
Wood	*	0	0	0	0	0	0	0	0	0
Total	**11**	**12**	**12**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
Total All Sectors										
Coal	18	18	18	18	18	18	18	18	18	18
Fuel Oil[a]	8	7	6	6	6	6	7	6	7	7
Natural Gas	19	23	23	22	21	22	21	21	21	21
LPG	3	4	4	3	4	4	4	4	4	4
Wood	516	529	387	346	370	386	330	280	320	297
Total	**564**	**580**	**437**	**395**	**419**	**437**	**379**	**328**	**369**	**346**

*Less than 500 metric tons methane.

[a]Fuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, AP 42, Fifth Edition (Washington, DC, January 1995), web site www.epa.gov/ttn/chief/ap42; Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), web site www.ipcc.ch/pub/guide.htm; and Energy Information Administration, *State Energy Data Report*, DOE/EIA-0214 (Washington, DC, various years), *Monthly Energy Review*, DOE/EIA-0035(2004/07) (Washington, DC, July 2004), and *Annual Energy Review*, DOE/EIA-0384 (Washington, DC, various years).

Table 20. U.S. Methane Emissions from Mobile Sources, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Thousand Metric Tons Carbon Dioxide Equivalent										
Motor Vehicles										
Passenger Cars	3,284	2,505	2,464	2,233	2,212	2,180	2,134	2,091	1,913	1,903
Buses	21	24	25	26	28	28	26	25	25	25
Motorcycles	92	95	97	99	102	101	93	92	92	92
Light-Duty Trucks	1,402	1,601	1,665	1,577	1,548	1,528	1,497	1,496	1,465	1,537
Other Trucks	271	339	354	363	375	380	387	397	400	400
Total	**5,070**	**4,564**	**4,606**	**4,299**	**4,265**	**4,217**	**4,136**	**4,102**	**3,893**	**3,956**
Other Transport	525	518	494	473	494	519	489	483	434	402
Total Transport	**5,596**	**5,082**	**5,100**	**4,773**	**4,759**	**4,736**	**4,626**	**4,585**	**4,328**	**4,358**
Thousand Metric Tons Methane										
Motor Vehicles										
Passenger Cars	143	109	107	97	96	95	93	91	83	83
Buses	1	1	1	1	1	1	1	1	1	1
Motorcycles	4	4	4	4	4	4	4	4	4	4
Light-Duty Trucks	61	70	72	69	67	66	65	65	64	67
Other Trucks	12	15	15	16	16	17	17	17	17	17
Total	**220**	**198**	**200**	**187**	**185**	**183**	**180**	**178**	**169**	**172**
Other Transport	23	23	21	21	21	23	21	21	19	17
Total Transport	**243**	**221**	**222**	**208**	**207**	**206**	**201**	**199**	**188**	**189**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

Sources: For passenger cars and light-duty trucks, 1990-2000 vehicle miles traveled (VMT) data are based on 2002 data on vehicle stocks provided by R.L. & Polk Co., with VMT modified by Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book: Edition 23* (Oak Ridge, TN, October 2003), Chapter 7. 1996-2000 data were further adjusted using fleet data and survival curves for the population of aging vehicles. For years after 2000, emissions data are based on fleet data, econometrically modeled VMT, and survival curves for the population of aging vehicles. Calculations for buses, motorcycles, and other trucks are based on VMT from Federal Highway Administration, U.S. Department of Transportation, *Federal Highway Statistics*, Table VM-1 (various years). Vehicle emissions coefficients are from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 1.65-1.75, web site www.ipcc.ch/pub/guide.htm. Fuel consumption data for non-highway sources are from Energy Information Administration, *Fuel Oil and Kerosene Sales*, DOE/EIA-0535 (Washington, DC, various years); *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years), and ORNL, *Transportation Energy Data Book: Edition 23* (Oak Ridge, TN, October 2003), Chapter 9, web site http://www-cta.ornl.gov/data/chapter9.html.

Table 21. U.S. Methane Emissions from Landfills, 1990 and 1996-2004

Type	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Gross Emissions from MSW Landfills	260.5	258.3	257.5	257.0	256.4	261.4	265.2	270.8	277.3	284.8
Emissions from Industrial Landfills	18.2	18.1	18.0	18.0	17.9	18.3	18.6	19.0	19.4	19.9
Methane Recovered for Energy (-)	15.6	26.2	31.8	38.0	42.1	46.9	52.7	55.7	59.8	63.3
Methane Assumed Flared (-)	6.1	30.3	35.7	41.9	44.9	49.5	55.3	60.6	58.9	58.9
Net Emissions	**257.0**	**219.8**	**208.1**	**195.0**	**187.4**	**183.3**	**175.8**	**173.4**	**178.1**	**182.6**
Million Metric Tons Methane										
Gross Emissions from MSW Landfills	11.3	11.2	11.2	11.2	11.1	11.4	11.5	11.8	12.1	12.4
Emissions from Industrial Landfills	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9
Methane Recovered for Energy (-)	0.7	1.1	1.4	1.7	1.8	2.0	2.3	2.4	2.6	2.8
Methane Assumed Flared (-)	0.3	1.3	1.6	1.8	2.0	2.2	2.4	2.6	2.6	2.6
Net Emissions	**11.2**	**9.6**	**9.0**	**8.5**	**8.1**	**8.0**	**7.6**	**7.5**	**7.7**	**7.9**

*Less than 50,000 metric tons carbon dioxide equivalent.

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

Sources: Municipal solid waste landfilled in 2002 from "Nationwide Survey: The State of Garbage in America," *Biocycle* (January 2004). Municipal solid waste generated and landfilled in previous years from "Nationwide Survey: The State of Garbage in America," *Biocycle* (various years), adjusted on the basis of residential demolitions, to reflect exclusion of construction and demolition waste as in the 2002 data. Municipal waste landfilled in 2003 based on 2002 estimate, scaled to annual economic growth. Emissions calculations based on S.A. Thorneloe et al., "Estimate of Methane Emissions from U.S. Landfills," Prepared for the U.S. Environmental Protection Agency, Office of Research and Development (April 1994), and D. Augenstein, "The Greenhouse Effect and U.S. Landfill Methane," *Global Environment Change* (December 1992), pp. 311-328. Methane recovered and flared from U.S. Environmental Protection Agency, Landfill Methane Outreach Program, web site www.epa.gov/lmop/. Emissions from industrial landfills estimated at 7 percent of methane emissions from municipal solid waste landfills, based on U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

Table 22. U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990 and 1996-2004

Animal Type	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Million Metric Tons Carbon Dioxide Equivalent										
Cattle	113.6	116.4	113.5	111.5	111.8	110.9	109.7	110.2	110.8	109.9
Swine	1.6	1.7	1.8	1.9	1.9	1.8	1.8	1.9	1.9	1.9
Sheep	2.1	1.6	1.5	1.4	1.3	1.3	1.3	1.2	1.2	1.1
Goats	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1
Horses	2.1	2.1	2.1	2.2	2.1	2.2	2.2	2.2	2.2	2.2
Total	**119.6**	**122.0**	**119.1**	**117.2**	**117.3**	**116.3**	**115.1**	**115.7**	**116.2**	**115.2**
Million Metric Tons Methane										
Cattle	4.94	5.06	4.94	4.85	4.86	4.82	4.77	4.79	4.82	4.78
Swine	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Sheep	0.09	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05
Goats	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Horses	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10
Total	**5.20**	**5.30**	**5.18**	**5.10**	**5.10**	**5.06**	**5.01**	**5.03**	**5.05**	**5.01**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: Cattle, sheep, and pig population data provided by the U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Service. Goat and horse population figures extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture*, 1982, 1987, 1992, and 1997. Emissions calculations based on U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissions USEmissionsInventory2005.html; and P.J. Crutzen, I. Aselmann, and W.S. Seiler, "Methane Production by Domestic Animals, Wild Ruminants, Other Herbivorous Fauna, and Humans," *Tellus*, Vol. 38B (1986), pp. 271-284.

Table 23. U.S. Methane Emissions from the Solid Waste of Domesticated Animals, 1990 and 1996-2004

Animal Type	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Thousand Metric Tons Carbon Dioxide Equivalent										
Cattle										
Beef Cattle	4,037	4,814	4,682	4,592	4,547	4,496	4,470	4,454	4,433	4,406
Dairy Cattle	12,717	15,992	16,829	16,970	17,092	17,430	17,746	18,014	18,185	18,267
Swine										
Market Swine	19,222	20,543	22,522	23,366	22,522	22,368	22,627	22,724	23,165	23,522
Breeding Swine	3,502	3,681	3,893	3,739	3,488	3,507	3,470	3,390	3,362	3,340
Poultry										
Layers	1,663	1,838	1,871	1,913	1,979	2,016	2,052	2,076	2,082	2,114
Broilers	1,590	2,199	2,266	2,298	2,372	2,255	2,284	2,339	2,312	2,379
Other Animals										
Sheep	115	33	31	31	28	28	27	26	25	24
Goats	16	16	14	12	11	11	12	10	10	10
Horses	624	633	636	644	636	645	652	652	652	652
Total	**43,486**	**49,750**	**52,744**	**53,564**	**52,676**	**52,756**	**53,340**	**53,685**	**54,226**	**54,715**
Thousand Metric Tons Methane										
Cattle										
Beef Cattle	176	209	204	200	198	195	194	194	193	192
Dairy Cattle	553	695	732	738	743	758	772	783	791	794
Swine										
Market Swine	836	893	979	1,016	979	973	984	988	1,007	1,023
Breeding Swine	152	160	169	163	152	152	151	147	146	145
Poultry										
Layers	72	80	81	83	86	88	89	90	91	92
Broilers	69	96	99	100	103	98	99	102	101	103
Other Animals										
Sheep	5	1	1	1	1	1	1	1	1	1
Goats	1	1	1	1	*	*	1	*	*	*
Horses	27	28	28	28	28	28	28	28	28	28
Total	**1,891**	**2,163**	**2,293**	**2,329**	**2,290**	**2,294**	**2,319**	**2,334**	**2,358**	**2,379**

*Less than 500 metric tons methane.
P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: Population data for horses and goats extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture*, 1982, 1987, 1992, and 1997. Population data for all other animals from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990, Report to Congress* (Washington, DC, April 1993), p. 6-8; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), Table M-2, web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html. Cattle sizes adjusted by annual slaughter weight from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Maximum methane production, and waste management systems used from L.M. Safley, M.E. Casada, et al., *Global Methane Emissions from Livestock and Poultry Manure* (Washington, DC: U.S. Environmental Protection Agency, February 1992), pp. 24-27; U.S. Environmental Protection Agency, *Cost Methodology Report for Beef and Dairy Animal Feeding Operations*, EPA-821-R-01-019 (Washington, DC, January 2001), pp.1-13–1-14; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2002*, EPA-430-R-04-003 (Washington, DC, April 2004), Table M-2. General methane conversion factors from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 4.25, web site www.ipcc.ch/pub/guide.htm. State methane conversion factors for dairy cattle from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2001); and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2002*, EPA-430-R-04-003 (Washington, DC, April 2004), Table M-4.

Table 24. U.S. Methane Emissions from Industrial Processes, 1990 and 1996-2004

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Thousand Metric Tons Carbon Dioxide Equivalent										
Chemical Production										
Ethylene	380	511	531	540	578	521	470	493	479	535
Ethylene Dichloride	58	79	84	82	91	82	78	78	83	101
Styrene	335	496	476	477	499	452	357	415	437	456
Methanol	174	245	267	262	254	203	142	137	132	123
Carbon Black	331	395	402	407	415	384	363	386	386	386
Total	**1,277**	**1,726**	**1,760**	**1,767**	**1,837**	**1,643**	**1,410**	**1,509**	**1,518**	**1,602**
Iron and Steel Production										
Coke[a]	251	193	172	163	148	155	130	132	132	132
Sinter	141	136	132	125	127	124	106	104	103	93
Pig Iron	1,028	1,023	1,027	998	958	991	872	833	841	875
Total	**1,420**	**1,352**	**1,330**	**1,286**	**1,233**	**1,271**	**1,108**	**1,068**	**1,077**	**1,100**
Total Industrial Processes	**2,697**	**3,078**	**3,090**	**3,053**	**3,070**	**2,914**	**2,518**	**2,577**	**2,594**	**2,702**
Thousand Metric Tons Methane										
Chemical Production										
Ethylene	17	22	23	23	25	23	20	21	21	23
Ethylene Dichloride	3	3	4	4	4	4	3	3	4	4
Styrene	15	22	21	21	22	20	16	18	19	20
Methanol	8	11	12	11	11	9	6	6	6	5
Carbon Black	14	17	17	18	18	17	16	17	17	17
Total	**56**	**75**	**77**	**77**	**80**	**71**	**61**	**66**	**66**	**70**
Iron and Steel Production										
Coke[a]	11	8	7	7	6	7	6	6	6	6
Sinter	6	6	6	5	6	5	5	5	4	4
Pig Iron	45	44	45	43	42	43	38	36	37	38
Total	**62**	**59**	**58**	**56**	**54**	**55**	**48**	**46**	**47**	**48**
Total Industrial Processes	**117**	**134**	**134**	**133**	**133**	**127**	**109**	**112**	**113**	**117**

[a]Based on total U.S. production of metallurgical coke, including non-iron and steel uses.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: American Iron and Steel Institute, *Annual Statistical Report* (Washington, DC, various years); American Chemical Council (formerly the Chemical Manufacturers Association), *U.S. Chemical Industry Statistical Handbook* (Washington, DC, various years); and Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 2.23, web site www.ipcc/pub/guide.htm.